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GEL PERMEATION CHROMATOGRAPHY IN THE FIELD OF PETROLEUM CHEMISTRY

By H. H. Oelert

Principles

[65]*

The separation of substances by liquid chromatography using porous gels (GPC) depends in typical cases only on the elution effect (1, 2) and may be expressed by a linear relationship between the elution volume and the logarithm of the molar volume or the molecular mass. However, this relationship is generally not applicable to substances having structures which differ from each other. For a system composed of a gel and an

* *Numbers in the right-hand margin indicate the corresponding page numbers in the original text - Tr.*

elution medium, straight lines are obtained whose positions are determined by the structure of the appropriate group of substances (3 to 9). A simple elution model can no longer be applied here. For a specific group of substances, differences in the relationship also become apparent depending on the type of the gel. This is illustrated in Fig. 1 using measurements on polyphenyls (benzene and sexiphenyl). Polystyrene (1) as well as dextran gels generally manifest the expected line with a negative slope characteristic for the prevailing elution effect in the appropriate elution medium. However with an alcohol elution medium, the dextran gels behave differently (3), which may be explained by the prevailing true separating mechanism (11). Silicate structures of glass gels are characterized by their large sorption capacity. When using a highly desorbing elution agent (isopropanol), the characteristics of the elution effect are still manifested (4). The steep slope may be explained by the large pore diameter (10 nm) of these substances. However, if a weak elution medium (cyclohexane) is used, the elution chromatography changes to sorption chromatography (5). The selection of the sorption medium therefore also has a large effect. This is well illustrated in Fig. 2, which shows the elution behaviour of various aromatic substances on glass gels. The measured elution volume was mathematically reduced by the fraction corresponding to the molar volume (9). The expression Ve(s)/Vt gives, in a relative manner, the fraction of the elution volume corresponding to the sorption, and is expressed in relation to the number of carbon atoms in the various aromatic substances. Polyphenyls (I) were eluted using cyclohexane and carbon chloride in a similar manner. Cata-condensed aromatic substances (II) manifest a higher retention when chromatographed using cyclohexanes than carbon chloride. The elution of peri-condensed aromatic substances (III) using cyclohexane cannot be expressed in a reasonable range of volumes. However, when the desorption efficiency of the elution

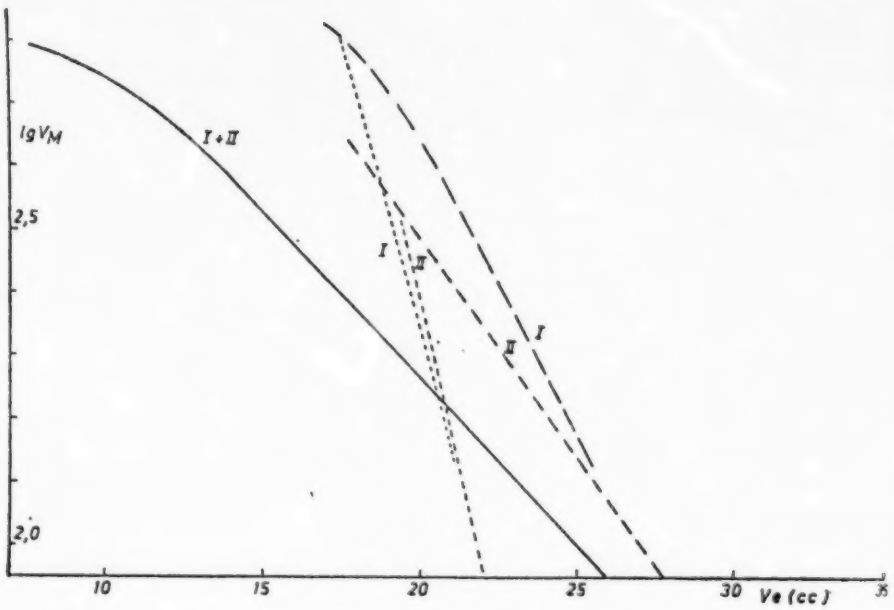
medium is increased, an identical behaviour is observed even with benzene for all three classes of substances, and the sorption effect is nearly cancelled. These few examples are sufficient to illustrate that a uniform typical behaviour cannot be expected in the chromatographic separation of hydrocarbons using gels. The equation [66]

$$V_e = a \log V_m + b$$

is valid for a large range of structures only if an appropriate elution agent is selected so that the mutual effects on the gel and the substance are balanced. For hydrocarbons, it was possible to approach this state only in one case (7). In the triple system of gel-elution medium-substance, the atypical behaviour may be generally expressed by the equation

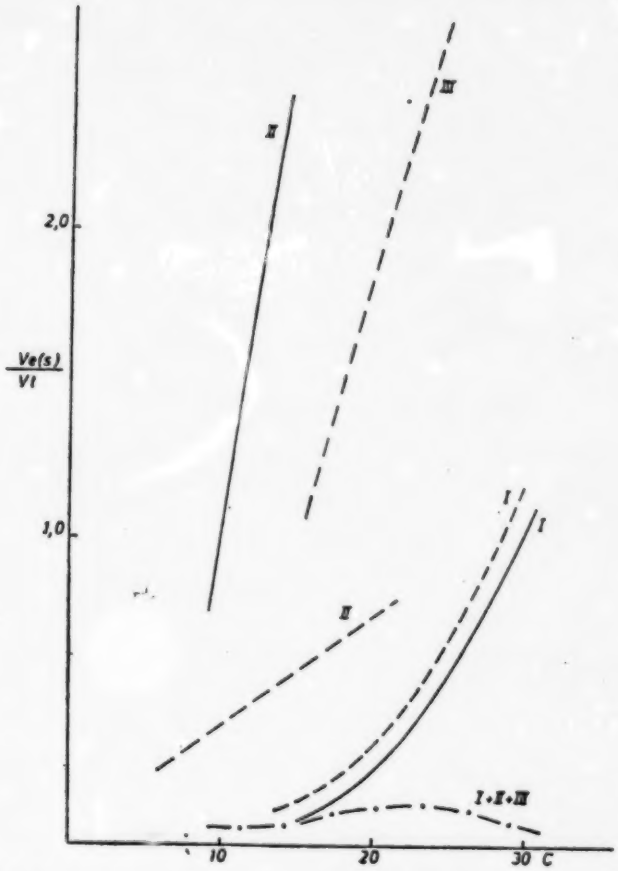
$$\frac{V_e}{V_{tg,e}} = a \log V_m + f(J)_{g,e} + G_{g,e}.$$

where J represents the potential of the effect of the substance, and G represents a geometric constant. In this form, the equation is at first specific for a given system (g for the gel and e for the elution medium). For a group of substances with a uniform structure, the function f(J) generally becomes a constant k, and the contribution of J may frequently be derived from an auxiliary variable, for example the number of π electrons (6). This trend to phenomenological theory, however, is still very far from suggesting a general solution. For certain regions, it is possible to derive empirical relationships, which provide a basis for the forecast of the separability of substances.



Obr. 1. Závislosť logaritmu mólového objemu polyfenylov (benzénu až sexifenylu) od elučného objemu vzťahnutého na objem stĺpca pre rôzne gély
1 — poragél A-1/metylénchlorid (4,6), poragél A-1/tetrahydrofurán (10), 2 — sephadex LH-20/THF (3), 3 — sephadex LH-20/izopropanol (11), 4 — sklený gél XOA-500/izopropanol (8,9), 5 — sklený gél XOA-500/cyklohexanol (8,9)

Fig. 1. Relationships between the molar volume of polyphenyls (benzene to sexiphenyl) and the elution volume in relation to the column volume for various gels.
1 - Poragel A-1/methylene chloride (4, 6), Poragel A-1/tetrahydrofuran (10), 2 - Sephadex LH-20/THF (3), 3 - Sephadex LH-20/isopropanol (11), 4 - XOA-500 silica gel/isopropanol (8, 9), 5 - XOA-500 silica gel/cyclohexanol (8, 9).



Obr. 2. Závislosť redukovaného relatívneho elučného objemu od počtu uhlíkov v polyfenyloch (I), katakondenzovaných (II) a perikondenzovaných aromátoch (III) na sklenom géli XOA-500 v rôznych elučných prostrediach
cyklohexán ——— chlorid uhličitý - - - benzén -.-.-.-.-

Fig. 2. Relationships between the reduced relative elution volume and the number of carbons in polyphenyls (I), cata-condensed aromatic substances (II), and peri-condensed aromatic substances (III) on XOA-500 silica gel in various elution environments.
cyclohexane ——— ; carbon chloride - - - - ; benzene - · - · -

Characteristic	Effect on			Remarks
	Elution volume	Zone width	Separation efficiency	
gel porosity	s	m	s	
chemical structure of the gel	v	v-m	v	depends on the elution medium and the substance separated
elution medium	v	w-m	v	depends on the chemical structure of the gel and the substance separated
particle size and packing density	w	s	s	uniformity of size and shape is important
dimensions of the separation path	-	w-m	v	
temperature	-	w	w	research carried out only for atypical GPC
pressure	-	w	w	increased pressure is possible only for some gels. Special relationships exist at higher pressures, usually characterized by greater separation efficiency
flow rate	w	s	s	generally the most important characteristic
loading (sample mass)	-	w-s	m-s	little effect up to the borderline loading. Possibility of secondary displacement
loading (sample volume)	w	m	m	in general, an additive effect

Fig. 3. Effect of individual characteristics on gel chromatography of oil hydrocarbons (w = weak; m = medium; s = strong; v = variable)

All of this is only a small part of the basic and experimental problems of gel chromatography and its application to crude oil. Fig. 3 shows an experiment in which attempts were made to obtain an understanding of the effect of some of the more important characteristics. A more detailed discussion cannot be included here and the reader should examine new and more detailed papers covering this topic (12, 13, 14, 15). We may state that despite the evident disadvantages such as a small number of separable bands, this method has advantages such as a relatively high load capacity, high reproducibility, and the possibility of using this method for separating groups of substances, which cannot be separated by other methods. An efficient use of this method requires that in all cases the characteristics which affect the separation be selected specifically in view of the problem being analyzed. [67]

Application [68]

In summarizing the possible uses, we are limited to examining only some of the characteristic examples from the various regions. From the viewpoint of production technology, one must differentiate between analytical chromatography using direct monitoring and evaluation of chromatograms and preparatory chromatography using separation and subsequent evaluation of fractions.

The method of analytical chromatography is suitable particularly for a rapid and reproducible comparison of fractions. Fig. 4 shows the separation curves of three different crude oils based on differences in refraction indices at a high elution rate. Asphalt components are found in the region between 11 and 12 mL, and fractions having a low molecular mass are found in the region between 17 and 25 mL. Differences in the medium

molecular masses in crude oils are manifested more clearly in the general course of the separation than in the location of the peaks. However, all such chromatograms may be interpretted in different ways. The high reproducibility should be emphasized as well as rapidity because the elution is completed in approximately 15 minutes.

More detailed information may be obtained by prior separation of the fractions using special analytical chromatography (11). Fig. 5 shows a chromatogram of selected aromatic fractions of crude oils which are characterized by absorption in the ultraviolet region. The crude oil was first separated on a silica gel into two fractions, one containing saturated hydrocarbons and the other containing aromatic hydrocarbons. These fractions were separated into additional fractions by gel chromatography carried out in the sorption variant (16). In the chromatograms shown, the increasing aromatic nature shifts the elution significantly to the right, and the alkane substitutions shift the elution slightly to the left (11). Accordingly, the high-molecular components of Fraction 1 are represented [69] by ring structures strongly influenced by alkyl substituents and their aromatic nature is distinctly manifested only at the bend in the curve in the vicinity of the 130 mL elution volume. However, the peak of the medium-molecular component of Fraction 2 is also located in this region.

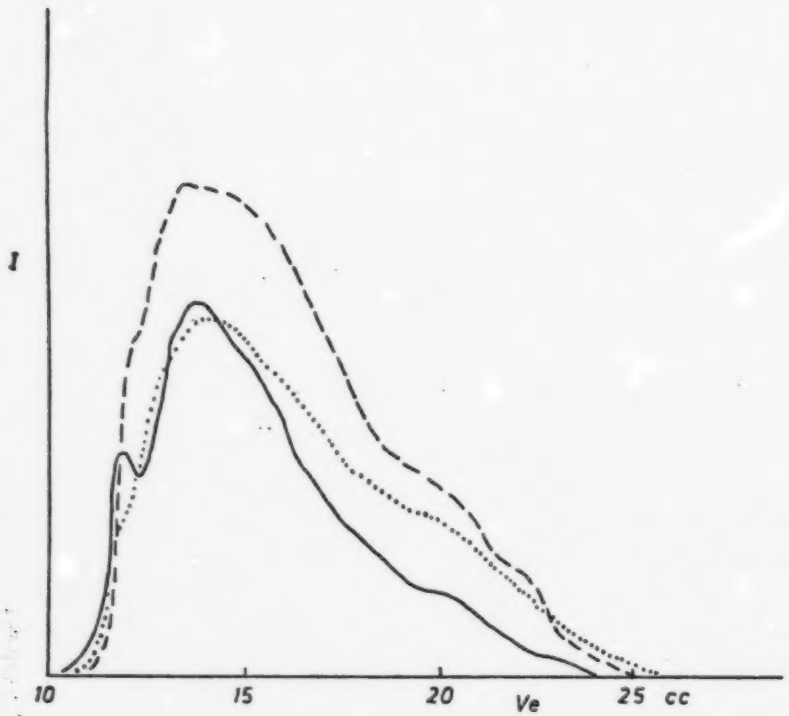
In the region of the low-molecular components of Fraction 3, the influence of the alkyl groups recedes to such an extent that distinct peaks belonging to various aromatic types become apparent. According to measurements carried out on model substances, it may, for example, be possible to attribute the peak at 270 mL to substituted substances having 4 or 5 aromatic rings, and the peak at 190 mL may be attributed to substituted substances with 4 aromatic rings or to substances having 3 slightly substituted rings. The peak in Fraction 2 is assumed to result from the presence of substances based on 3 and 4 condensed aromatic rings which

have alkyl substituents consisting of 15 to 25 carbon atoms; this assumption was made on the basis of chromatographic data and molecular mass values. Very detailed information may be obtained in conjunction with spectroscopic measurements of the fractions isolated in this manner.

By first calibrating the chromatograms, it is possible to obtain important data as shown in Fig. 6 for chromatograms of saturated oil fractions. From the differences in the refraction indices on the ordinate, the volume percentages were derived by using the measurements obtained with authentic substances. In a similar way, using authentic substances, elution volumes on the abscissa were attributed to molecular masses. Thus, the medium positions, read from the scales for oils 31 and 56, correspond with sufficient accuracy to the measured mean molecular masses. The data for oil 65 have only limited validity in view of the low elution limit of the gel used. However, there is a sufficient guarantee that it is possible to directly read the separation of molecular masses at least in the upper elution region. In using axes having the units mL/mL and mL, it is possible to directly integrate the separation curves and in this way directly obtain the volume components of the oil for the regions selected. [70]

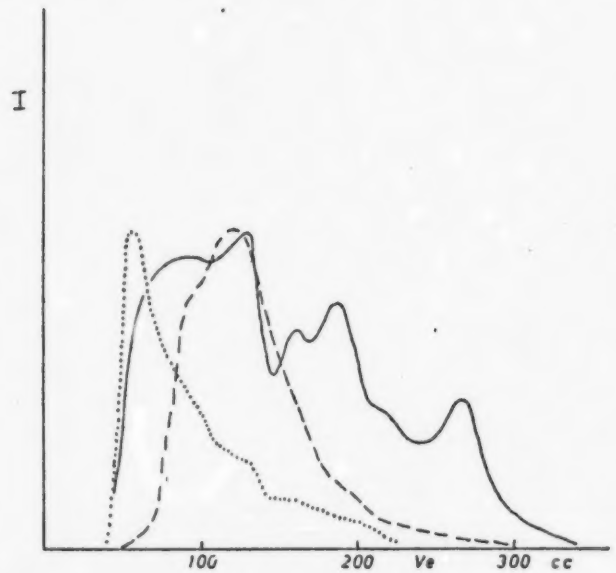
Additional more recent studies concerning analytical chromatography deal with oils (7, 16, 17, 18), asphalts (7, 19, 20, 21), porphyrins (22), crude oil residues (23, 24), oil sprays (23), viscous oils (16, 25), tall oils (26), and water polution by oil (18).

The preparation variant, which is associated with greater work and time demands, does not differ in principle from the analytical variant; however, it is useful when additional data on the fractions isolated need to be obtained for subsequent studies. At the present time, gel permeation chromatography is used for studying heterocompounds in crude oil and in oil sprays, which are important from the production viewpoint. The following examples have been selected from this region. [71]



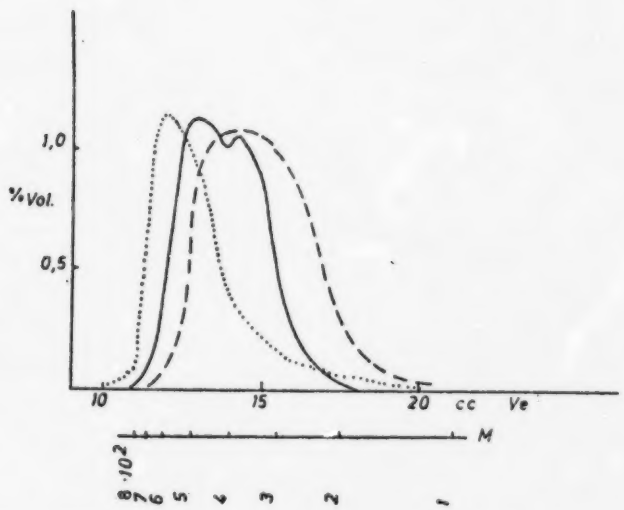
Obr. 4. Závislosť výchylky zapisovača (rozdielu indexov lomu) od elučného objemu pre rôzne ropy
Merckogel OR-750/metylénchlorid; stĺpec 60 × 1 cm; 30 mg vzorky, T 295 °K, v 0,9 mm/s)
barenhöfská (M410)
nienhagenská (M360)
gernsheimská (M330)

Fig. 4. Relationships of the recorder deviations (differences in the refraction indices) and the elution volumes for various crude oils.
(Merckogel OR-750/methylene chloride; column 60 x 1 cm; 30 mg samples; T = 295 K; v = 0.9 mm/s)
Crude oils:
——— Barenhof (M410); - - - Nienhagen (M360); ····· Gernsheim (M330)



Obr. 5. Závislosť výchylky zapisovača (absorpcia v UV pri 254 nm) od elučného objemu vopred oddelených frakcií aromatického podielu (získaného na silikagéle) nienhagenskej ropy (Predbežné delenie: sklenný gél XOA-500/chloroform; stĺpec 160 × 1,75 cm, 1 g vzorky, T 293 °K, v′ = 0,4 ml/min, objem frakcií 8 ml)
(Vlastné delenie: Sephadex LH-20/izopropanol, stĺpec 52 × 1,75 cm, 10 mg vzorky, T 293 °K, v′ = 0,4 ml/min)
1. frakcia (M1690) .... 2. frakcia (M487) – – – 3. frakcia (M306) ——

Fig. 5. Relationships between the recorder deviations (ultraviolet absorption at 254 nm) and the elution volumes of previously separated fractions of the aromatic components (retained on the silica gel) of Nienhagen crude oil. (Preliminary separation: XOA-500 silica gel/chloroform; column 160 x 1.75 cm; 1 g sample; T = 293 K; v' = 0.4 mL/min; aliquots = 8 mL). (Separation proper: Sephadex LH-20/isopropanol, column 52 x 1.75 cm; 10 mg samples; T = 293 K; v' = 0.4 mL/min).
Fraction 1 (M1690) ···· ; Fraction 2 (M487) - - - ; Fraction 3 (M306) ——



Obr. 6. Závislosť percentuálneho obsahu nasýtených olejových podielov od elučného objemu (molekulovej hmotnosti) (Merckogel OR-750/metylénchlorid, stĺpec 60 × 1 cm, 30 mg vzorky, T 295 °K, v = 0,09 mm/s)
č. 65 (M800) .... č. 31 (M530) —— č. 56 (M410) - - - -

Fig. 6. Relationships between the percentage contents of saturated oil components and the elution volumes (molecular masses). (Merckogel OR-750/methylene chloride; column 60 x 1 cm; 30 mg samples; T = 295 K; v = 0.09 mm/s).
No. 65 (M800) ····· ; No. 31 (M530) ——— ; No. 56 (M410) - - - -

The total content of heteroatoms and molecular masses were measured in the fractions of aromatic components of sprays used for catalytic cracking and other processes. Fig. 7 shows the heteroatom content in relation to the molecular mass for six oils. The occurrence of valleys is typical, but this must be attributed in part to the separation characteristics of the gel chromatography used. From the curves obtained, it is possible to calculate the mass separation of heteroatoms as well as the initial correlation basis for the solution of technical problems by using quantity balance methods.

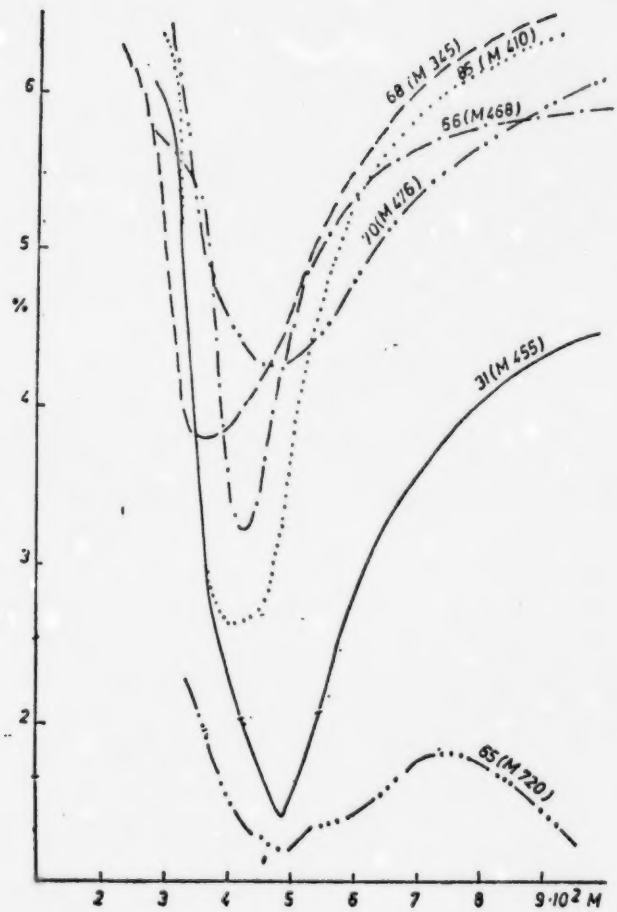
By using multi-level ion exchange and complex chromatography, it is possible to separate the groups of acidic, basic, and neutral nitrogen-containg substances from each other in crude oils and sprays. Gel chromatography then permits the determination of regions from which the individual components have been separated. Fig. 8 shows such a separation before and after heteroatoms have been removed from California crude oil. It is evident that the components having a low molecular mass were not affected to a considerable extent, whereas the entire asphalt region was affected by the separation. According to this finding, heteroatoms occur in the region where the molecular masses are between 20,000 and 8,000 as well as in the region between 500 and 350.

In order to obtain better characteristics, the components of this crude oil containing heteroatoms were separated from the fraction boiling at 400°C to 500°C and were then subjected to preparatory gel chromatography. The molecular masses were determined in the narrow fractions obtained. Fig. 9, showing the separation of individual components, was obtained in this way. The hydrocarbons show a slightly uneven distribution in the region of molecular masses ranging from 200 to 600 with a noticeable bend in the curve around 300. The distribution of bases is similar,

but the values are shifted by approximately 100 toward the higher molecular masses. The bend in the curve for lower molecular masses is missing, [73] but a second peak is present for a value of approximately 850. This higher molecular region predominates in acidic compounds, which may probably be explained by dimerization, although even then the molecular mass of the base is higher than that of the hydrocarbons. Infrared spectra of the fractions provided information about the general structure of these substances. Nuclear magnetic resonance (NMR) spectra, and particularly mass spectra with a high resolution facilitate a detailed study of the structures found.

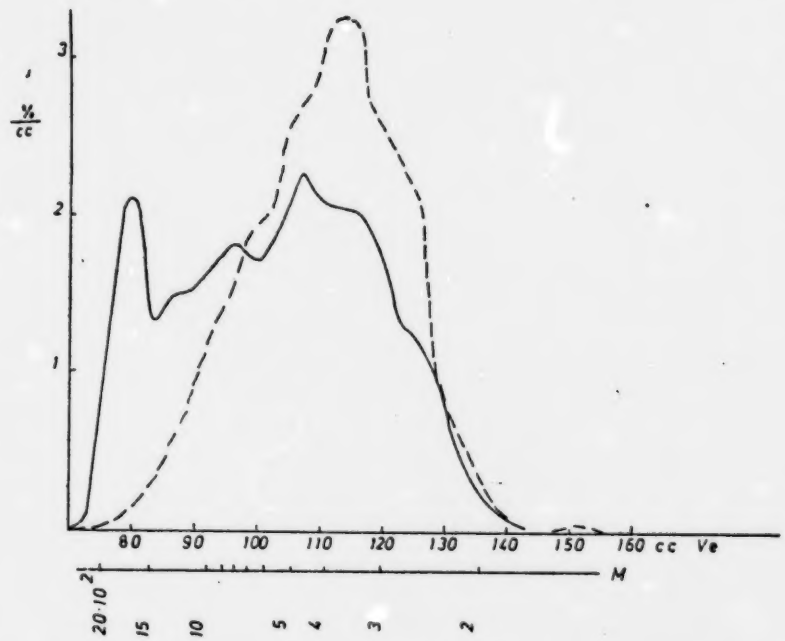
Other papers, in which preparatory chromatography has been used, deal with the following substances: crude oil (4, 16, 17, 27), asphalt (28, 29), porphyrins (35, 36), aromatic oil fractions (16, 17, 27, 31), saturated oil fractions (5, 16, 27, 33, 34), and fractions containing heteroatoms (23, 29, 30, 37).

The use of spectral methods for oil fractions obtained from gel permeation chromatography has also been described: infrared (27, 29, 30), nuclear magnetic resonance (24, 27, 29, 30), and mass spectrometry (5, 31, 37).



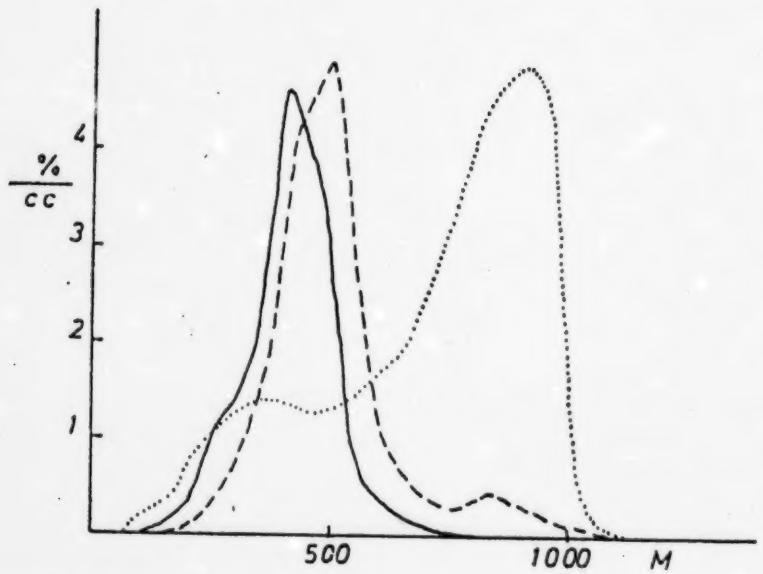
Obr. 7. Závislosť percentuálneho obsahu heteroatómov od molekulovej hmotnosti aromatického podielu olejových nástrekov (oleje sú označené číslom a strednou molekulovou hmotnosťou)
(Sephadex LH-20/chloroform, stĺpec 100 × 1,8 cm, 1 g vzorky, T 290 °C, v' = 0,6 ml/min)

Fig. 7. Relationships between the percentage contents of heteroatoms and the molecular masses of the aromatic components of oil sprays (the oils are designated by numbers and mean molecular masses).
(Sephadex LH-20/chloroform; column 100 x 1.8 cm; 1 g samples; T = 290°C; v' = 0.6 mL/min).



Obr. 8. Závislosť množstevného podielu eluovaného na jednotku objemu od elučného objemu ropy pred ——— a po - - - - oddelení heteroatómových podielov
(Poragél A-1/metylénchlorid, stĺpce 152 × 1,27 cm, 200 mg vzorky, T 290 °C, v' = = 0,8 ml/min)

Fig. 8. Relationships between the amounts of the components eluted per unit volume and the elution volumes of crude oil before ——— and after - - - - separating the components containing heteroatoms.
(Poragel A-1/methylene chloride; column 152 x 1.27 cm; 200 mg samples; T = 290°C; v' = 0.8 mL/min).



Obr. 9. Závislosť množstevného podielu eluovaného na jednotku objemu od nameranej molekulových hmotností pre frakcie ropy z rezu 400—300 °C
uhľovodíky —— zásady - - - - kyseliny ..... (pokusné podmienky ako na obr.

Fig. 9. Relationships between the amounts of the components eluted per unit volume and the measured molecular masses for crude oil fractions in the range of 400°C to 500°C.
hydrocarbons ——— ; bases - - - ; acids •••••
(Experimental conditions were the same as in Fig. 8).

Summary

The basic concepts of gel permeation chromatography in the field of petroleum chemistry under typical and atypical conditions, as well as the effect of the gels, elution media, and substances which are to be separated, are discussed. A general relationship for the normal course of gel permeation chromatography is described. Substantial effects of experimental variables on the elution volumes, widths of the zones, and heights of the separating columns are mentioned. As an example, analytical records of separating curves of crude oils and their aromatic and saturated oil components are presented. Working procedures used in isolating, separating, and evaluating components containing heteroatoms in crude oils and oil sprays are presented. A complete review of the recent technical literature is provided.

References

Literatúra

1. J. Porath: Pure Appl. Chem. 6 (1963) 233
2. T. C. Laurent, J. Killander: J. Chromatog. 14 (1963) 317
3. B. C. B. Hsieh, R. E. Wood, L. L. Anderson, G. R. Hill: Anal. Chem. 41 (1969) 1066
4. H. H. Oelert, D. R. Latham; W. E. Haines: Div. Petrol. Chem. ACS, Preprints Vol 15 No 2 (1970) A-204
5. J. H. Weber, H. H. Oelert: Div. Petrol. Chem. ACS, Preprints Vol 15, No 2 (1970) A-212
6. H. H. Oelert, J. H. Weber: Erdöl u. Kohle (v tlači)
7. J. G. Bergmann, L. J. Duffy: Div Petrol. Chem. ACS, Preprints Vol 15, No 2 (1970) A-217
8. American Petrol Institute, Res. Proj 60; Spring Meeting, Bartlesville 197
9. H. H. Oelert: Westdeutsche Chemie dozententagung, Köln 1970, Vortrag A-42
10. T. Edstrom, B. A. Petro: J. Polym. Sci. C (1068) 171
11. H. H. Oelert: Z. Anal. Chem. 244 (1969) 91
12. Proceedings of the 5th Intern. Dem. on GPC, London 1968, publ. by Waters Ass. Framinham Mass.

11. Preprints of the 6th Intern. Sem. on GPC, Miami Beach Fla. 1968 publ. by Waters Ass. Framinggam Mass.
14. Div. Petrol. Chem. ACS, Preprints Vol 15, No 2 (1970) A-7 — A-203
15. J. C. Giddings: Anal. Chem. 38 (1966) 997; 39 (1967) 1027; 40 (1968) 2142
16. H. H. Oelert: Erdöl u. Kohle 22 (1969) 536
17. H. H. Oelert: J. Chromatog. (zadané)
18. J. N. Donne, W. K. Reid: Div. Petrol. Chem. ACS, Preprints Vol. 15, No 2 (1970) A-242
19. K. H. Altgelt: J. Appl. Polym. Sci. 9 (1965) 3389
20. K. H. Altgelt: Makromol. Chem. 88 (1965) 75
21. W. B. Richman: Proces. Ass. Asphalt Paving Techn. 36 (1967) 106
22. M. Blumer, W. D. Snyder: Chem. Geol. 2 (1967) 35
23. E. W. Albaugh, P. C. Talarico, B. E. Davis, R. A. Wirkala: Div. Petrol. Chem. ACS, Preprints Vol 15 No 2 (1970) A-225
24. F. E. Dickson, R. A. Wirkala, B. W. Davis: Div. Petrol. Chem. ACS, Preprints Vol 15 No 2 (1970) A-233
25. L. E. Maley; J. Polym. Sci. C 8 (1965) 253
26. T. L. Chang: Anal. Chem. 40 (1968) 989
27. H. H. Oelert: Erdöl u. Kohle 22 (1969) 19
28. C. A. Stout, S. W. Nicksic: Div. Petrol. Chem. ACS, Preprints Vol 15, No 2 (1970) A-254
29. K. H. Altgelt, E. Hirsch: Div. Petrol. Chem. ACS, Preprints Vol 15, No 2 (1970) A-262
30. H. H. Oelert: American Petroleum Institute, Res. Proj. 60; Summer Meeting, St. Knight Camp 1969
31. H. J. Coleman, D. E. Hirsch, J. E. Dooley; Anal. Chem. 41 (1969) 800
32. F. W. Dickson, B. W. Davis, R. Y. Wirkala: Anal. Chem. 41 (1969) 1335
33. P. C. Talarico, E. W. Albaugh, R. E. Snyder: Anal. Chem. 40 (1968) 2192
34. B. J. Mair, R. P. T. Hwang, R. G. Ruberto: Anal. Chem. 39 (1967) 838
35. H. P. Pohlmann, R. J. Roscup: 153rd Meeting ACS, Miami 1967, Abstracts
36. J. M. Sugihara, J. F. Branthaver, G. Y. Wu, C. Weatherbee: Div. Petrol. Chem. ACS, Preprints Vol 15, No 2 (1970) C-5
37. W. K. Seifert, R. M. Teeter, W. G. Howell, M. J. R. Cantow: Anal. Chem. 41 (1969) 1638

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